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Marie [CA/CA]; 1954 Mulberry Crescent, Gloucester,  
Ontario K1J 8J9 (CA).

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(74) Agent: **ANDERSON, Wayne, J.**; National Research  
Council of Canada, Intellectual Property Services, EG-12,  
Bldg. M-58, 1200 Montreal Road, Ottawa, Ontario K1A  
0R6 (CA).

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(71) Applicant (*for all designated States except US*): **NA-  
TIONAL RESEARCH COUNCIL OF CANADA**  
[CA/CA]; 1200 Montreal Road, Bldg. M-58, Room  
EG-12, Ottawa, Ontario K1A 0R6 (CA).

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(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **LI, Yuning**  
[CN/CA]; #701-240 Brittany Drive, Ottawa, Ontario  
K1K 0R7 (CA). **DING, Jianfu** [CA/CA]; Apt. 10,699  
La Verendrye Drive, Gloucester, Ontario K1J 7X5 (CA).  
**DAY, Michael** [CA/CA]; 994 Buckskin Way, Orleans,  
Ontario K1C 2Y6 (CA). **TAO, Ye** [CA/CA]; 1671 Place  
des Ravins, Ottawa, Ontario K1Ck 6H5 (CA). **D'IORIO,**

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(54) Title: THERMALLY CROSSLINKABLE MATERIALS AND MULTI-LAYERED DEVICES THEREFROM

(57) Abstract: The invention disclosed relates to cross-linkable composites of boronic acid or a boronic acid derivative such as a boronate, and an organic or organo-metallic moiety having a functionality such as hole transporting, electron transporting and light emitting, to cross-linked composites and to methods for making same. Multi-layer materials and optoelectronic devices including such cross-linked composites are also disclosed.

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by Art. 19*

## CLAIMS:

1. A cross-linkable composite of boronic acid or a boronic acid derivative such as a boronate, and an organic or organo-metallic moiety having a functionality such as hole transporting, electron transporting and light emitting.
2. A method of making a cross-linkable composite of boronic acid or a boronic acid derivative derivative such as a boronate, and an organic or organo-metallic moiety having a functionality such as hole transporting, electron transporting and light emitting, comprising attaching to boronic acid or a boronic acid derivative, an organic or organo-metallic moiety having a functionality such as hole transporting, electron transporting and light emitting.
3. A cross-linked composite of boronic acid or a boronic acid derivative derivative such as a boronate, and an organic or organo-metallic moiety having a functionality such as hole transporting, electron transporting and light emitting.
4. A method of making a cross-linked composite of boronic acid or a boronic acid derivative such as a boronate, and an organic or organo-metallic moiety having a functionality such as hole transporting, electron transporting and light emitting, comprising attaching to boronic acid or a boronic acid derivative, an organic or organo-metallic moiety having a functionality such as hole transporting, electron transporting and light emitting, and cross-linking.
5. A multi-layer material comprising a plurality of layers of a cross-linked composite of boronic acid or a boronic acid derivative such as a boronate, and an organic or organo-metallic moiety having a functionality such as hole transporting, electron transporting and light emitting, wherein each layer has a different functionality.
6. A multi-layer photoelectronic device, comprising in sequence, a transparent substrate layer, a transparent electrode layer, a layer of a transparent cross-linked composite of boronic acid or a boronic acid derivative such as a boronate, and an organic or organo-metallic

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by art. 19*

moiety having a functionality such as hole transporting, electron transporting and light emitting, at least one another such layer having a different functionality such as hole transporting, electron transporting and light emitting, and another transparent electrode layer.

7. A method of making a multi-layer material comprising a plurality of layers of a cross-linked composite of boronic acid or a boronic acid derivative such as a boronate, and an organic or organo-metallic moiety having a functionality such as hole transporting, electron transporting and light emitting, comprising forming on a substrate a layer of a cross-linked composite of boronic acid or a boronic acid derivative and an organic or organo-metallic moiety having a functionality such as hole transporting, electron transporting and light emitting, and cross-linking, and forming at least one another such layer having a different functionality such as hole transporting, electron transporting and light emitting and cross-linking.

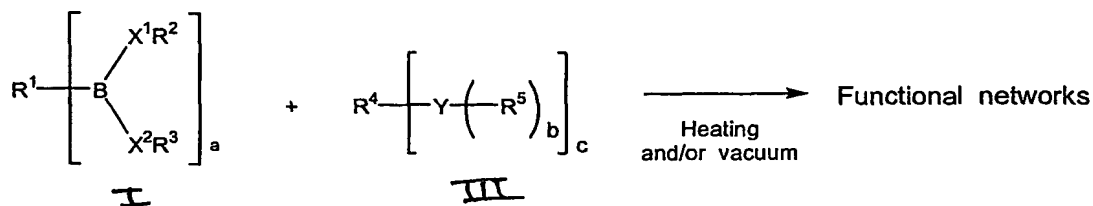
8. A method according to Claim 4 or 7, wherein the cross-linking is effected by heating under vacuum.

9. A method according to Claim 8, wherein heating is effected at a temperature of from room temperature up to 130 °C.

10. A cross-linkable material of boronic acid or a boronic acid derivative such as a boronate, and an organic or organo-metallic moiety having a functionality such as hole transporting, electron transporting and light emitting, wherein the material is formed from a) a single boronic acid, b) a composite of two or more different boronic acids, c) a composite of one boronic acid or its derivative with one or more other materials which contain groups reactive with boronic acid or its derivative, and d) a composite of any number of boronic acids or its derivatives (at least one) with any number and any kinds of other materials which contain groups (listed in the formula at Figure 10) reactive with boronic acid or its derivative)

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by Art. 19*

11. A method of making cross-linked functional networks, comprising reacting compound of structural formula I with a compound of structural formula III



whereas,

$\text{R}^1$ , and  $\text{R}^4$  = alkyl, aryl, or other groups, either organic or inorganic, but at least one of them contains functionality; they can be of small molecular weights or high molecular weights.

$\text{R}^2$ ,  $\text{R}^3$ ,  $\text{R}^5$  = H, alkyl, aryl, they may be same or different, but at least one of them is H.

$\text{X}^1$ ,  $\text{X}^2$  = O, S, or N, they may be same or different.

$\text{Y}$  = O, S, N (or NH),  $\text{BO}_2$ ,  $\text{SiO}_2$ ,  $\text{AlO}_2$ ,  $\text{TiO}_3$ , etc.

$a$  and  $c$  are larger than one.

$b$  equal to 1, 2 or 3.